Analog absolute pressure sensor, 20 kPa to 550 kPa

Rev. 5.1 — 3 November 2023

Product data sheet



1 General description

The FXPS7550A4 high-performance, high-precision absolute pressure sensor consists of a compact capacitive micro-electro-mechanical systems (MEMS) device coupled with a digital integrated circuit (IC) producing a fully calibrated analog output.

This sensor is ideal for many automotive applications such as manifold air pressure (MAP), turbo MAP, comfort seating, and other applications requiring operating absolute pressure ranges up to 550 kPa.

The sensing element is based on NXP's high precision capacitive pressure cell technology. The architecture benefits from redundant pressure transducers as an expanded quality measure. It delivers highly accurate ratiometric analog readings of absolute pressure while operating from either a 3.3 V or 5.0 V power supply.

The sensor operates over a pressure range of 20 kPa to 550 kPa and over a wide temperature range of –40 °C to 130 °C.

The sensor comes in an industry-leading 4 mm x 4 mm x 1.98 mm, restriction of hazardous substances (RoHS) compliant, high-power quad flat no-lead (HQFN) package^[1] suitable for small printed circuit board (PCB) integration. Its AEC-Q100^[2] compliance, high accuracy, reliable performance, and high media resistivity make it ideal for use in automotive, industrial, and consumer applications.

2 Features and benefits

- Absolute pressure range: 20 kPa to 550 kPa
- Operating temperature range: -40 °C to 130 °C
- Analog output for monitoring of the absolute pressure signal
- Pressure transducer and digital signal processor (DSP)
 Internal self-test
- · Capacitance to voltage converter with anti-aliasing filter
- · Sigma delta ADC plus sinc filter
- 800 Hz or 1000 Hz low-pass filter for absolute pressure
- Lead-free, 16-pin HQFN, 4 mm x 4 mm x 1.98 mm package

3 Applications

3.1 Automotive

- Manifold air pressure
- MAP, TurboMAP
- Small engine control



Analog absolute pressure sensor, 20 kPa to 550 kPa

• Liquid propane gas (LPG) or compressed natural gas (CNG) engine management

3.2 Industrial

- Compressed air
- Manufacturing line control
- · Gas metering
- Weather stations

3.3 Medical/Consumer

- Blood pressure monitor
- Medicine dispensing systems
- White goods

4 Ordering information

Table 1. Ordering information

Type number	Package			
	Name	Description	Version	
FXPS7550A4	HQFN16	HQFN16, plastic, thermal enhanced quad flat pack; no leads; 16 terminals; 0.8 mm pitch; 4 mm x 4 mm x 1.98 mm body	SOT1573-1	

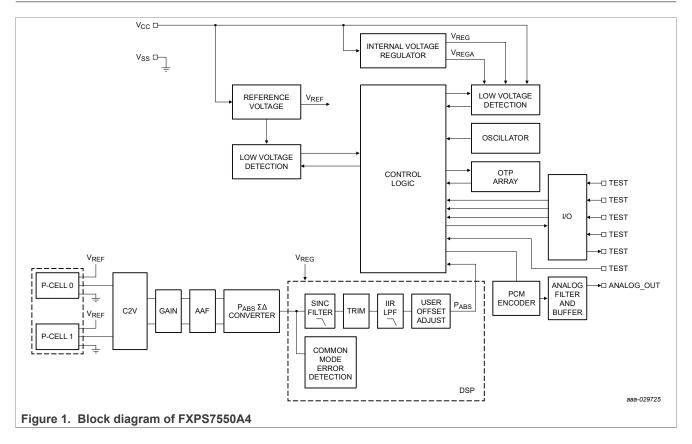
4.1 Ordering options

Table 2. Ordering options

Device	Range (kPa)	Packing	Temperature range
FXPS7550A4T1	20 kPa to 550 kPa	Packing Tape and Reel	–40 °C to 130 °C

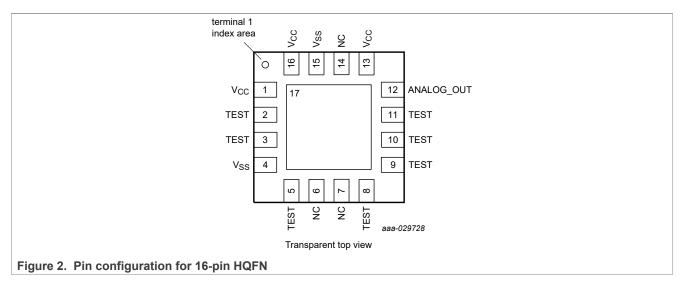
Analog absolute pressure sensor, 20 kPa to 550 kPa

5 Block diagram



6 Pinning information

6.1 Pinning



Analog absolute pressure sensor, 20 kPa to 550 kPa

6.2 Pin description

Table 3. Pin description

Pin	Pin name	Description
2, 8, 9, 10	TEST	Pins 2, 8, 9, and 10 are test pins and must be left unterminated in the application.
3	TEST	Pin 3 is required to be tied to V _{CC} for device operation.
4, 15	V _{SS}	Pins 4 and 15 are the supply return nodes and are connected internally to the die attach pad (pin 17).
5, 11	TEST	Pins 5 and 11 are test pins and must be tied to V _{SS} .
6, 7, 14	NC	Pins 6, 7 and 14 are not internally connected and can be left unconnected in the application.
12	ANALOG_OUT	Pin 12 provides a ratiometric analog output proportional to the absolute pressure sensor data.
1, 13, 16	V _{CC}	Pins 1, 13 and 16 supply power to the device. An external capacitor must be connected between these pins and V_{SS} , as shown in the application diagram.
17	PAD	Pin 17 is the die attach flag and must be connected to V_{SS} .

7 Functional description

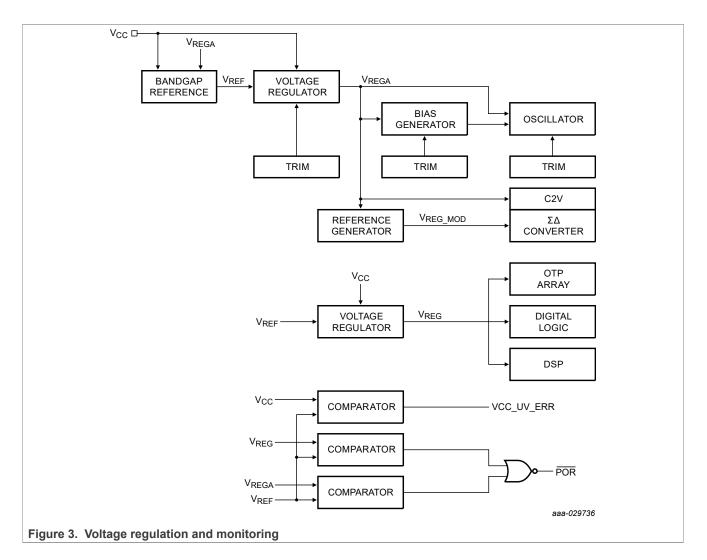
7.1 Voltage regulators

The device derives its internal supply voltage from the V_{CC} and V_{SS} pins. An external filter capacitor is required for V_{CC} , as shown in Figure 12.

A reference generator provides a reference voltage for the $\Sigma\Delta$ converter.

FXPS7550A4

Analog absolute pressure sensor, 20 kPa to 550 kPa



7.2 Pressure sensor signal path

7.2.1 $\Sigma\Delta$ converter

A second order sigma delta modulator converts the voltage from the analog front end to a data stream that is input to the DSP. A simplified block diagram is shown in <u>Figure 4</u>.

Analog absolute pressure sensor, 20 kPa to 550 kPa

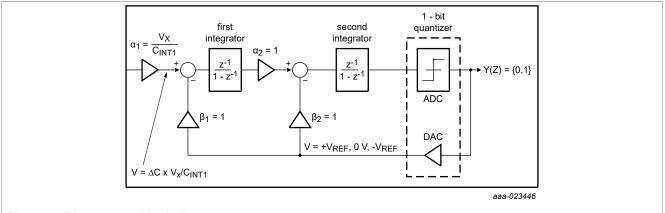


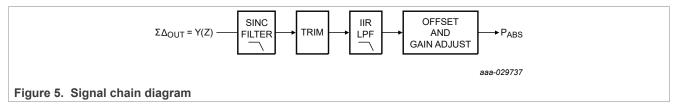
Figure 4. $\Sigma\Delta$ converter block diagram

The sigma delta modulator operates at a frequency of 1 MHz, with the transfer function in Equation 1.

$$H(Z) = \frac{\alpha_1}{Z^2} \tag{1}$$

7.2.2 Digital signal processor (DSP)

A DSP is used to perform signal filtering and compensation. A diagram illustrating the signal processing flow within the DSP is shown in <u>Figure 5</u>.

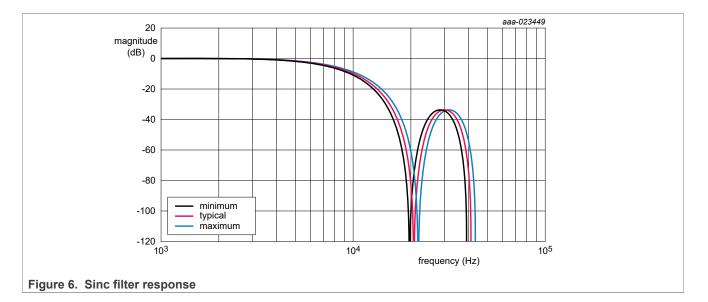


7.2.2.1 Decimation sinc filter

In Equation 2, the output of the $\Sigma\Delta$ modulator is decimated and converted to a parallel value by two third-order sinc filters; the first with a decimation ratio of 24 and the second with a decimation ratio of 4.

$$H(Z) = \left(\frac{1}{24^3}\right) \times \left(\frac{1 - Z^{-24}}{1 - Z^{-1}}\right)^3 \quad H(Z) = \left(\frac{1}{4^3}\right) \times \left(\frac{1 - Z^{-4}}{1 - Z^{-1}}\right)^3 \tag{2}$$

Analog absolute pressure sensor, 20 kPa to 550 kPa



7.2.2.2 Signal trim and compensation

The device includes digital trim to compensate for sensor offset, sensitivity, and nonlinearity over temperature.

7.2.2.3 Low-pass filter

Data from the sinc filter is processed by an infinite impulse response (IIR) low-pass filter with the transfer function and coefficients shown in Equation 3.

$$H(Z) = a_0 \times \frac{(n_{11} \times z^0) + (n_{12} \times z^{-1}) + (n_{13} \times z^{-2})}{(d_{11} \times z^0) + (d_{12} \times z^{-1}) + (d_{13} \times z^{-2})} \times \frac{(n_{21} \times z^0) + (n_{22} \times z^{-1}) + (n_{23} \times z^{-2})}{(d_{21} \times z^0) + (d_{22} \times z^{-1}) + (d_{23} \times z^{-2})}$$
(3)

Filter number	Typical –3 dB frequency	Filter order		Filter coeffic	cients (24 b	bit)	Group delay (μs)	Typical attenuation @ 1000 Hz (dB)
1	800 Hz	4	a ₀	0.088642612609670	-	-	418	4.95
			n ₁₁	0.029638050039039	d ₁₁	1		
			n ₁₂	0.087543281056143	d ₁₂	-1.422792640957290		
			n ₁₃	0.029695285913601	d ₁₃	0.511435253566960		
			n ₂₁	0.250241278804809	d ₂₁	1		
			n ₂₂	0.499999767379068	d ₂₂	-1.503329908017845		
			n ₂₃	0.249758953816089	d ₂₃	0.621996524706640		
2	1000 Hz	4	a ₀	0.129604264748411	-	_	333	2.99
			n ₁₁	0.043719804402508	d ₁₁	1		
			n ₁₂	0.087543281056143	d ₁₂	-1.300502656562698		
			n ₁₃	0.043823599710731	d ₁₃	0.430106921311110	1	
			n ₂₁	0.250296586927511	d ₂₁	1	1	
			n ₂₂	0.499999648540934	d ₂₂	-1.379959571988366]	
			n ₂₃	0.249703764531484	d ₂₃	0.555046257157745]	

 Table 4. IIR low pass filter coefficients

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FXPS7550A4

Analog absolute pressure sensor, 20 kPa to 550 kPa

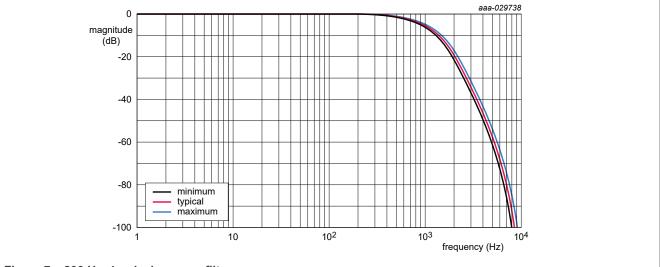
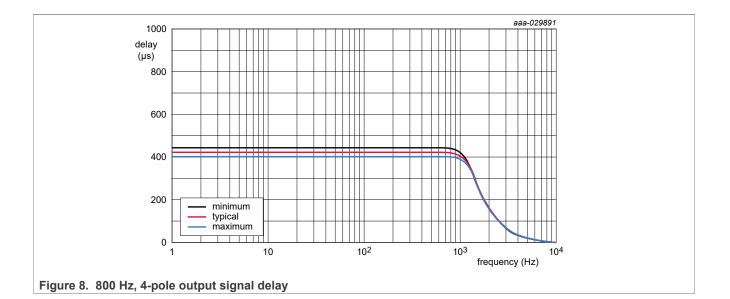


Figure 7. 800 Hz, 4-pole, low-pass filter response



FXPS7550A4

Analog absolute pressure sensor, 20 kPa to 550 kPa

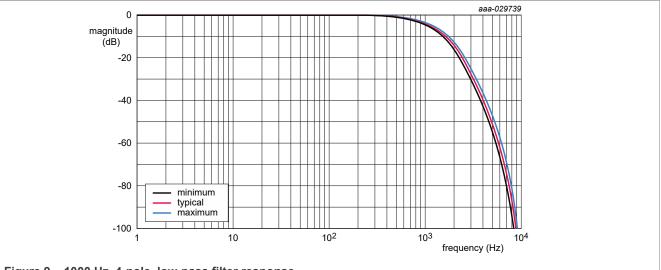
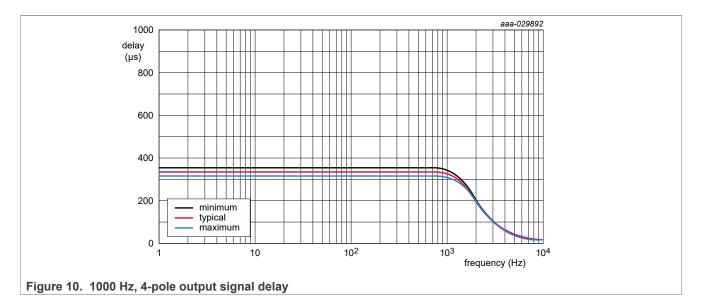


Figure 9. 1000 Hz, 4-pole, low-pass filter response



7.3 Analog output function

7.3.1 Analog output signal chain

The device provides an analog output ratiometric to the supply voltage. The analog output is enabled by default. Selecting the analog output enables the following functions:

- The non-interpolated P_{ABS} sensor data output is saturated to 10 bits and converted to an unsigned value.
- The 10-bit sensor value is input into a summer clocked at 10 MHz.
- The carry from the summer circuit generates a PCM output.
- The PCM signal is filtered by a 2-pole active low pass filter to generate an analog signal.

7.3.2 Analog output transfer function

The FXPS7550A4 device provides an analog output voltage ratiometric to the supply voltage.

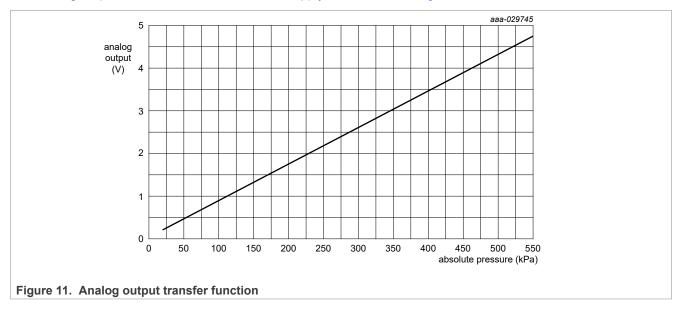
Analog absolute pressure sensor, 20 kPa to 550 kPa

If using a supply voltage other than 5 V, the general form of the transfer function should be applied as described in equation <u>Equation 4</u>:

$$Pressure_k Pa = -3.0415 + 576.0369 \times (A_{OUT}/V_{CC})$$
(4)

In addition, the absolute pressure analog offset, P_{OFF} and output voltage span, V_{FSS} , then becomes a ratio of their magnitude by applying the ratio of (V_{CC} / 5 V) to each of these parameters.

There can be slight variations in the P_{OFF} and V_{FSS} based on the temperature. The minimum and maximum variation of P_{OFF} and V_{FSS} can be assessed by applying the same ratio (V_{CC} / 5 V) to both of these parameters and then applying the error percentages to obtain these variations if needed.



The analog output transfer function for a 5.0 V supply is as shown in Figure 11.

8 Maximum ratings

Absolute maximum ratings are the limits that the device can be exposed to without permanently damaging it. Absolute maximum ratings are stress ratings only; functional operation at these ratings is not guaranteed. Exposure to absolute maximum ratings conditions for extended periods might affect device reliability.

This device contains circuitry to protect against damage due to high static voltage or electrical fields. NXP advises that normal precautions be taken to avoid application of any voltages higher than maximum-rated voltages to this high-impedance circuit.

Table 5.	Maximum	ratings
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Symbol	Parameter	Conditions	Min	Мах	Unit
VCC _{MAX}	Supply Voltage	V _{CC} , V _{CCIO} ^[1]	-	+6.0	V
V _{IOMAX}	Input/Output Max on pins	ANALOG_OUT ^[1] TESTx	-0.3	V _{CC} + 0.3	V
h _{DROP}	Drop shock	To concrete, tile or steel surface, 10 drops, [2] any orientation	_	1.2	m
T _{stg}	Temperature range	Storage ^[2]	-40	+130	°C
TJ		Junction ^[3]	-40	+150	°C

Analog absolute pressure sensor, 20 kPa to 550 kPa

Table 5. Maximum ratings...continued

Symbol	Parameter	Conditions		Min	Max	Unit
P _{MAX}	Maximum absolute pressure	Continuous	[3]	_	600	kPa
P _{BURST}		Burst (tested at 100 ms)	[2]	—	1650	kPa
P _{MIN}	Minimum absolute pressure	Continuous	[1]	—	20	kPa
f _{SEAL}	Pressure sealing force	Applied to top face of package	[1]	—	10	N
θ _{JA}	Thermal resistance		[4]	—	120	°C/W
ESD and latch-up	protection characteristics					
V _{ESD}	Electrostatic discharge (per	Human body model (HBM)	[2]	-2000	2000	V
V _{ESD}	AEC-Q100, Rev H)	Charge device model (CDM)	[2] [5]	-500	500	V

Parameter verified by parametric and functional validation. [1]

Parameter verified by qualification testing (Per AEC-Q100 Rev H or per NXP specification).

[2] [3] [4] Functionality verified by modeling, simulation and/or design verification.

Thermal resistance provided with device mounted to a two-layer, 1.6 mm FR-4 PCB as documented in AN1902^[1] with one signal layer and one ground layer.

[5] CDM tested at ±750 V for corner pins and ±500 V for all other pins.



Caution

This device is sensitive to mechanical shock. Improper handling can cause permanent damage to the part.



Caution This is an ESD sensitive device. Improper handling can cause permanent damage to the part.

Operating range 9

Table 6. Electrical characteristics — supply and I/O

 $V_{CC_min} \le (V_{CC} - V_{SS}) \le V_{CC_max}, T_L \le T_A \le T_H, \Delta T \le 25 \text{ °C/min}, unless otherwise specified.$

Symbol	Parameter	Conditions	Min	Max	Units
V _{CC}	Supply voltage	Measured at V _{CC} ^[1]	3.10	5.25	V
T _A	Operating temperature range	V _{CC} = 5.0 V, unless otherwise stated. Production tested operating temperature ^[1] range	T _L -40	Т _Н +130	°C
T _A		Guaranteed operating temperature range [1]	-40	+130	°C
V _{CC_RAMP}	Supply power on ramp rate	[2] [3]	0.00001	10	V/µs

Parameter tested at final test. [1]

Functionality verified by modeling, simulation and/or design verification. [2]

[3] Parameter verified by parametric and functional validation.

Analog absolute pressure sensor, 20 kPa to 550 kPa

Static characteristics 10

Table 7. Static characteristics

 $V_{CC_min} \le (V_{CC} - V_{SS}) \le V_{CC_max}, T_L \le T_A \le T_H, \Delta T \le 25 \text{ °C/min, unless otherwise specified.}$

Symbol	Parameter	Condition		Min	Тур	Max	Units
Supply and I/O		1				I	
lq	Supply current	V _{CC} = 5.0 V	[1]	—	_	8.0	mA
Temperature sen	sor signal chain	1					
V _{OH_ANA}	Output high voltage	ANALOG_OUT, I _{Load} = -100 μA	[1]	V _{cc} - 0.2	-	—	V
V _{OL_ANA}	Output low voltage	ANALOG_OUT, I _{Load} = 100 μA	[1]	_	-	0.2	V
V _{OUT_3dB}	Analog output low-pass filter frequency typical value	–3 dB, 2-pole	[2]	8	-	20	kHz
V _{OUT_3dBTol}	Analog output low-pass filter frequency typical tolerance	-3 dB, 2-pole	[2]	-5	-	5	%
Absolute pressur	re sensor signal chain	·					
P _{ABS}	Absolute pressure range		[1] [3]	20	_	550	kPa
P _{SENS}	Absolute pressure output sensitivity	V _{CC} = 5.0 V. Tested at PA = 300 kPa and 400 kPa	[2]	_	8.68	_	mV/ kPa
P _{ACC_HIT}	Absolute pressure accuracy	V _{CC} = 5.0 V. 85 °C < T _A ≤ 130 °C	[4]	-3	-	+3	%FSS
P _{ACC_Typ}	Absolute pressure accuracy	$V_{CC} = 5.0 V.$ 0 °C ≤ T _A ≤ 85 °C	[4]	-2	-	+2	%FSS
P _{ACC_LoT}	Absolute pressure accuracy	$V_{CC} = 5.0 \text{ V.}$ -40 °C ≤ T _A < 0 °C	[4]	-3	-	+3	%FSS
P _{OFF}	Absolute pressure analog offset	At pressure span extremes V_{CC} = 5.0 V.	[4]	-	0.2	-	V
V _{FSS}	Output voltage span	At pressure span extremes $V_{CC} = 5.0 \text{ V}.$	[5]	-	4.6	-	V

[1]

Parameter verified by pass/fail testing at final test. Functionality verified by modeling, simulation and/or design verification. Parameter verified by characterization. [2] [3]

[4] [5] Parameter tested at final test.

Parameter verified by functional evaluation.

Analog absolute pressure sensor, 20 kPa to 550 kPa

11 Dynamic characteristics

Table 8. Dynamic characteristics

 $V_{CC_min} \le (V_{CC} - V_{SS}) \le V_{CC_max}, T_L \le T_A \le T_H, \Delta T \le 25 \text{ °C/min}, unless otherwise specified.$

Symbol	Parameter	Condition		Min	Тур	Max	Units
Signal chain							
t _{SigChain}	P _{ABS} low-pass filter	Signal chain sample time	[1]	_	48	-	μs
f _{c0}		Cutoff frequency, filter option #0, 4-pole	[1][2]	—	800	_	Hz
f _{c1}		Cutoff frequency, filter option #1, 4-pole	[1][2]	—	1000	-	Hz
t _{SigDelay}	Signal delay (sinc filter to output delay, excluding the P _{ABS} LPF)		[1]	—	-	128	μs
t _{Delay_DataValid}	Supply recovery	V _{CC} to sensor data valid		300	_	-	ms
f _{Package}	Package resonance frequency		[1]	27.1	_	-	kHz

[1] Functionality verified by modeling, simulation and/or design verification.

[2] Parameter verified by functional evaluation.

12 Media compatibility—pressure sensors only

For more information regarding media compatibility information, contact your local sales representative.

Note:

The devices contain a gel that protects the pressure transducer and its inter-die connection wires from corrosion, which might otherwise result in catastrophic failure modes. NXP has observed that direct exposure to materials with the same or nearly-the-same solubility can potentially result in a corruption of the protective gel. A corruption can be less than catastrophic in nature, however may result in an offset of the pressure measurement from its factory calibrated value. An offset can potentially be larger than the allowed tolerances published in this data sheet.

Further, NXP does not recommend direct exposure to strong acid or strong base compounds as they can potentially result in a similar corruption as described above, or may result in a dissolution of the protective gel and/or the metal lid adhesive and/or the plastic device body. Such a dissolution can be catastrophic in nature, damaging the transducer surfaces and/or internal wire bonds and/or the control die surfaces. A potential dissolution may result in a similar offset, or cause the device to indicate overflow/underflow status, or may cause the device to cease operating in the worst case.

For a list of compounds known to generate out-of-tolerance offsets and/or catastrophic device failure, please contact an NXP sales representative.

13 Application information

Note: A gel is used to provide media protection against corrosive elements which may otherwise damage metal bond wires and/or IC surfaces. Highly pressurized gas molecules may permeate through the gel and then occupy boundaries between material surfaces within the sensor package. When decompression occurs, the gas molecules may collect, form bubbles and possibly result in delamination of the gel from the material it protects. If a bubble is located on the pressure transducer surface or on the bond wires, the sensor measurement may shift from its calibrated transfer function. In some cases, these temporary shifts could be outside the tolerances listed in the data sheet. In rare cases, the bubble may bend the bond wires and result in a permanent shift.

Analog absolute pressure sensor, 20 kPa to 550 kPa

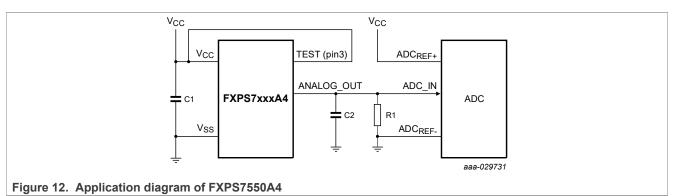
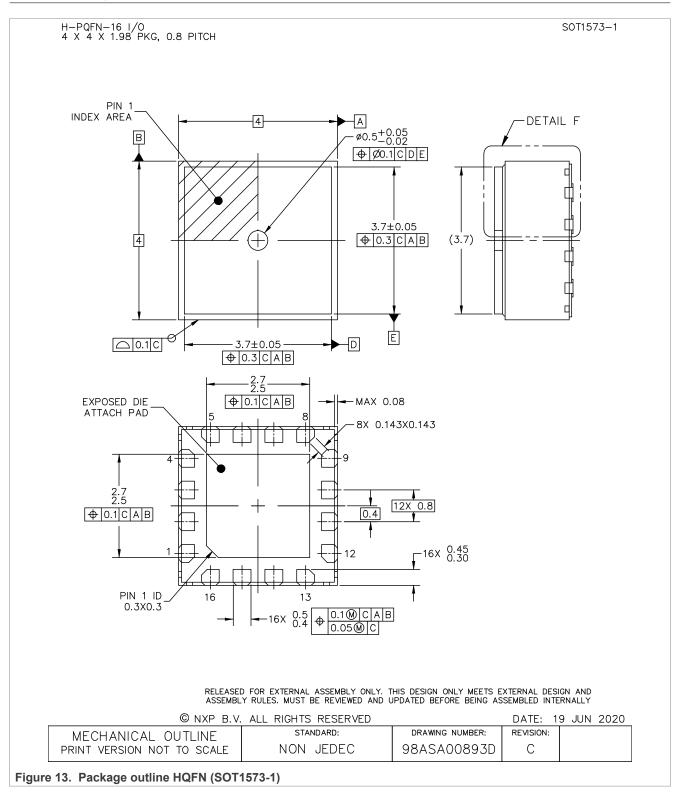


Table 9. External component recommendations

Name	Туре	Description	Purpose
C1	Ceramic	0.1 μF, 10 %, 10 V minimum, X7R	V _{CC} power supply decoupling
C2	Ceramic	47 pF, 10 %, 10 V minimum, X7R	Analog output filtering
R1	General purpose	51 kΩ, 5 %, 200 PPM	Analog output pull-down resistor

Analog absolute pressure sensor, 20 kPa to 550 kPa

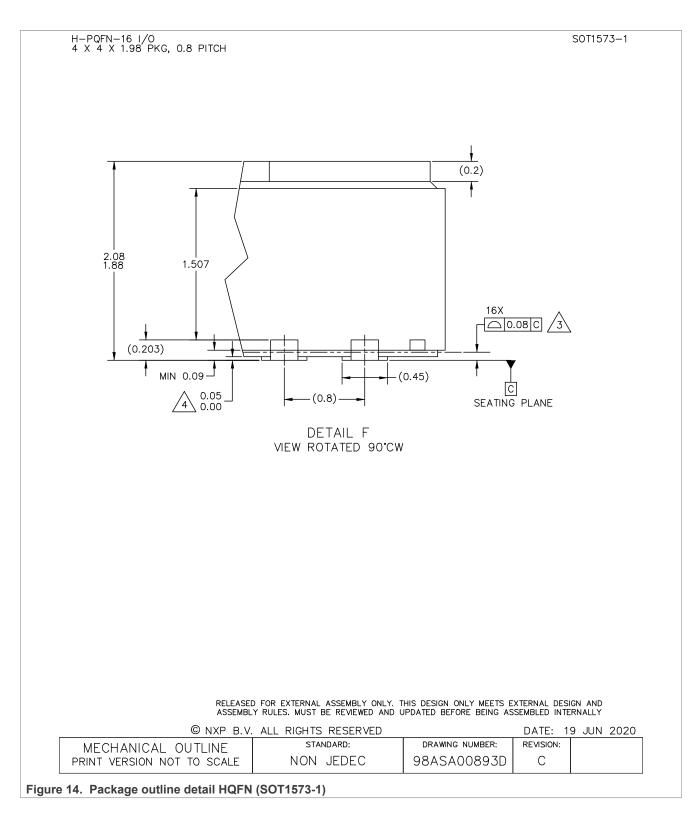
14 Package outline



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FXPS7550A4

Analog absolute pressure sensor, 20 kPa to 550 kPa



FXPS7550A4

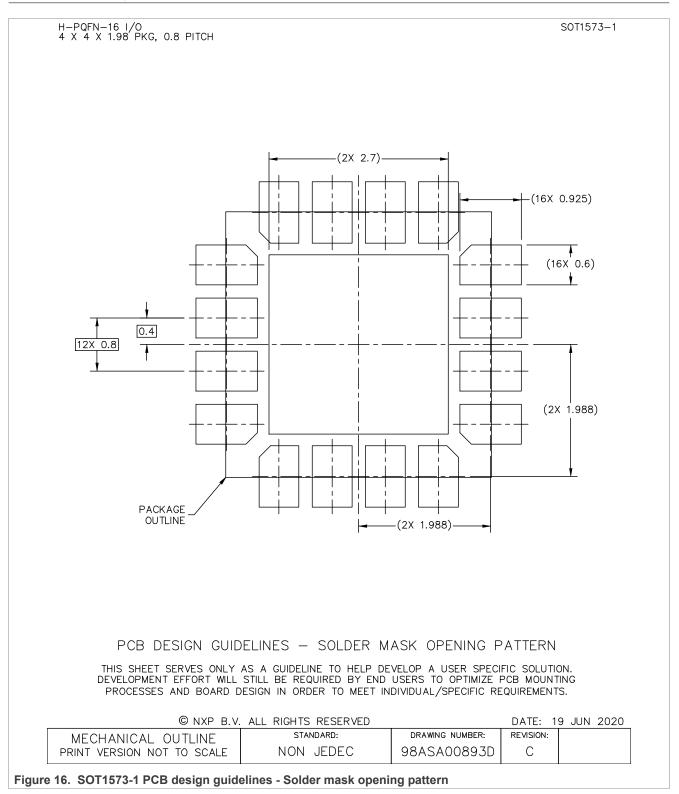
Analog absolute pressure sensor, 20 kPa to 550 kPa

H-PQFN-16 I/O 4 x 4 x 1.98 PKG, 0.8 PITCH	SOT1573-1
NOTES:	
1. ALL DIMENSIONS ARE IN MILLIMETERS.	
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.	
🔔 COPLANARITY APPLIES TO LEADS AND DIE ATTACH PAD.	
$\underline{\cancel{A}}$ dimension applies only for terminals.	
5. MIN METAL GAP SHOULD BE 0.2 MM.	
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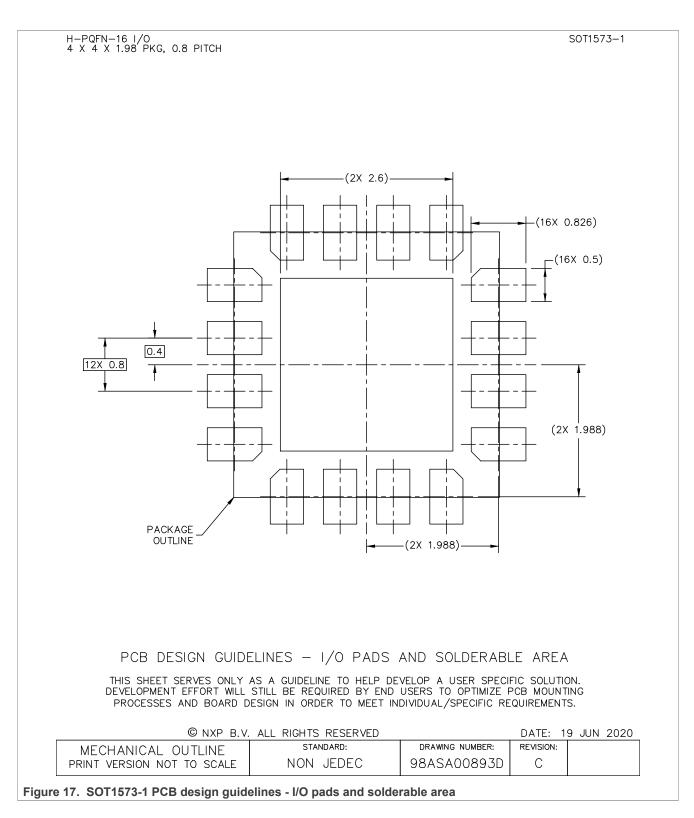
Figure 15. Package outline note HQFN (SOT1573-1)

Analog absolute pressure sensor, 20 kPa to 550 kPa

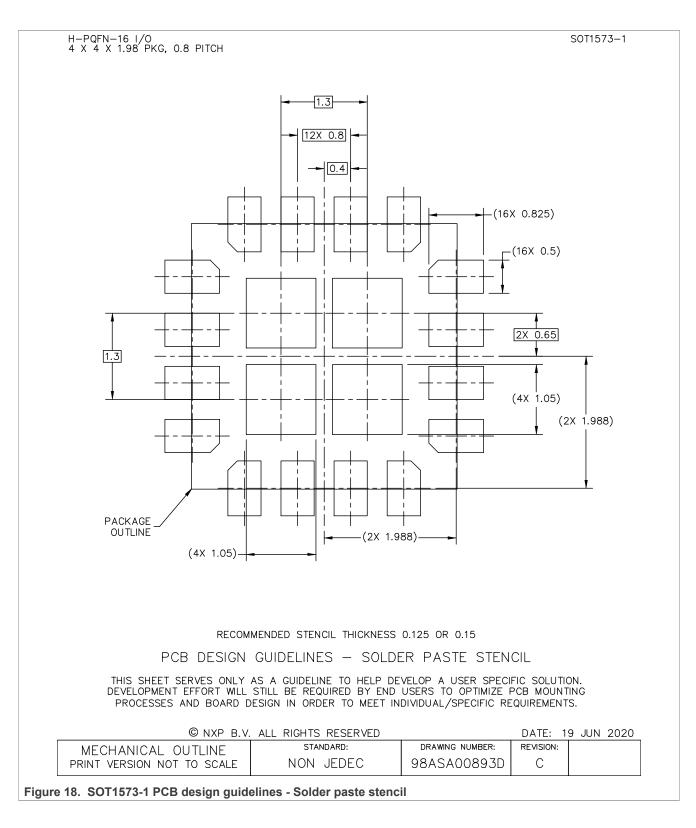
15 Soldering



Analog absolute pressure sensor, 20 kPa to 550 kPa



Analog absolute pressure sensor, 20 kPa to 550 kPa



Analog absolute pressure sensor, 20 kPa to 550 kPa

16 Mounting recommendations

The package should be mounted with the pressure port pointing away from sources of debris which might otherwise plug the sensor.

A plugged port exhibits no change in pressure and can be cross checked in the user software.

Refer to NXP application note AN1902^[1] for proper printed circuit board attributes and recommendations.

17 References

- [1] **AN1902** Assembly guidelines for QFN (quad flat no-lead) and SON (small outline no-lead) packages https://www.nxp.com/docs/en/application-note/AN1902.pdf
- [2] AEC documents on Automotive Electronics Council Component Technical Committee's site: http://www.aecouncil.com/AECDocuments.html

18 Revision history

Table 10. Revision history

	Data sheet status	Change notice	Supercedes
			•
20231103	Product data sheet	—	FXPS7550A4 v.5
• <u>Section 12</u> , inserte	ed a new disclaimer note.		
20220729	Product data sheet	—	FXPS7550A4 v.4.1
20190529	Product data sheet	—	FXPS7550A4 v.4
20190507	Product data sheet	—	FXPS7550A4 v.3
20190506	Preliminary data sheet	—	FXPS7550A4 v.2
20190408	Preliminary data sheet	—	FXPS7550A4 v.1
20180913	Preliminary data sheet	—	—
	20220729 20190529 20190507 20190506 20190408	 Section 12, inserted a new disclaimer note. 20220729 Product data sheet 20190529 Product data sheet 20190507 Product data sheet 20190506 Preliminary data sheet 20190408 Preliminary data sheet 	 Section 12, inserted a new disclaimer note. 20220729 Product data sheet — 20190529 Product data sheet — 20190507 Product data sheet — 20190506 Preliminary data sheet — 20190408 Preliminary data sheet —

Analog absolute pressure sensor, 20 kPa to 550 kPa

Legal information

Data sheet status

Document status ^{[1][2]}	Product status ^[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL <u>https://www.nxp.com</u>.

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Tables

Tab. 1.	Ordering information	.2
	Ordering options	
Tab. 3.	Pin description	.4
Tab. 4.	IIR low pass filter coefficients	.7
	Maximum ratings1	

Tab. 6.	Electrical characteristics — supply and I/O 11
Tab. 7.	Static characteristics 12
Tab. 8.	Dynamic characteristics 13
Tab. 9.	External component recommendations
Tab. 10.	Revision history21

Figures

Fig. 1.	Block diagram of FXPS7550A43
Fig. 2.	Pin configuration for 16-pin HQFN
Fig. 3.	Voltage regulation and monitoring5
Fig. 4.	ΣΔ converter block diagram6
Fig. 5.	Signal chain diagram 6
Fig. 6.	Sinc filter response7
Fig. 7.	800 Hz, 4-pole, low-pass filter response
Fig. 8.	800 Hz, 4-pole output signal delay8
Fig. 9.	1000 Hz, 4-pole, low-pass filter response 9
Fig. 10.	1000 Hz, 4-pole output signal delay9
Fig. 11.	Analog output transfer function10

Fig. 12. Fig. 13.	Application diagram of FXPS7550A414 Package outline HQFN (SOT1573-1)15
Fig. 13. Fig. 14.	Package outline detail HQFN (SOT1573-1) 16
Fig. 15.	Package outline note HQFN (SOT1573-1) 17
Fig. 16.	SOT1573-1 PCB design guidelines - Solder
-	mask opening pattern18
Fig. 17.	SOT1573-1 PCB design guidelines - I/O
	pads and solderable area19
Fig. 18.	SOT1573-1 PCB design guidelines - Solder
	paste stencil

FXPS7550A4

Analog absolute pressure sensor, 20 kPa to 550 kPa

Contents

1	General description	1
2	Features and benefits	1
3	Applications	
3.1	Automotive	
3.2	Industrial	
3.3	Medical/Consumer	
4	Ordering information	
4.1	Ordering options	2
5	Block diagram	3
6	Pinning information	
6.1	Pinning	
6.2	Pin description	
7	Functional description	4
7.1	Voltage regulators	
7.2	Pressure sensor signal path	5
7.2.1	ΣΔ converter	5
7.2.2	Digital signal processor (DSP)	6
7.2.2.1	Decimation sinc filter	
7.2.2.2	Signal trim and compensation	7
7.2.2.3	Low-pass filter	7
7.3	Analog output function	9
7.3.1	Analog output signal chain	9
7.3.2	Analog output transfer function	9
8	Maximum ratings	
9	Operating range	11
10	Static characteristics	12
11	Dynamic characteristics	13
12	Media compatibility—pressure sensors	
	only	13
13	Application information	13
14	Package outline	15
15	Soldering	
16	Mounting recommendations	
17	References	
18	Revision history	
	Legal information	22

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